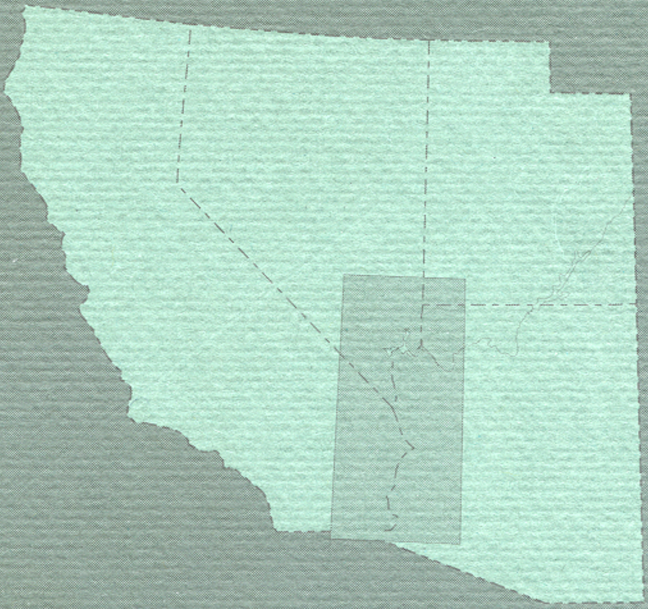
Method to Identify Wells That Yield Water That Will Be Replaced by Colorado River Water in Arizona, California, Nevada, and Utah

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 94—4005



Prepared in cooperation with the
BUREAU OF RECLAMATION

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By RICHARD P. WILSON
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U.S. DEPARTMENT OF THE INTERIOR
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PLATES—Continued

FIGURES

CONVERSION FACTORS

Multiply	By	To obtain
inch	2.54	centimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
acre	0.4047	square hectometer
acre-foot	0.001233	cubic hectometer
cubic foot per second	0.02832	cubic meter per second
gallon per minute	0.06309	liter per second

DEFINITION OF TERMS

Selected hydrologic and geologic terms used in the report are defined below. Terms were adapted from Bates and Jackson (1987), Lohman and others (1972), Meinzer (1923), and U.S. Water-Resources Council (1980) or were defined in this report.

Accounting surface (this report)—The accounting surface represents the elevation and slope of the unconfined static water table in the river aquifer outside the flood plain and the reservoirs of the Colorado River that would exist if the river were the only source of water to the river aquifer. The accounting surface was generated by using profiles of the Colorado River and water-surface elevations of reservoirs, lakes, marshes, and drainage ditches.

Acre-foot—The volume of water required to cover 1 acre to a depth of 1 foot; 43,560 cubic feet or 325,851 gallons.

Aquifer—A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Bedrock (this report)—Consolidated rocks that form the bottom and sides of the basins that underlie the Colorado River valley and adjacent tributary valleys and the mountain masses that rim the basins and valleys. The bedrock is nearly impermeable and is a barrier to ground-water flow.

Flood plain—A surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river in its existing regimen and covered with water when the river overflows its banks. In this report, the flood plain is that part of the Colorado River valley that has been covered by floods of the modern Colorado River as it meandered prior to the construction of Hoover Dam. The flood plain commonly is bounded by terraces and alluvial slopes that rise to the foot of mountains that rim the valley. The flood plain ranges in width from less than 1,000 feet where the river is confined in bedrock canyons to about 9 miles in Palo Verde Valley.

Geologic formation—A persistent body of igneous, sedimentary, or metamorphic rock, having easily recognizable boundaries that can be traced in the field without recourse to detailed paleontologic or petrologic analysis, and large enough to be represented on a map as a practical or convenient unit for mapping and description. Formations are described in geologic literature and have formal names (Bouse Formation) or informal names (younger alluvium).

River (this report)—The Colorado River and associated reservoirs, lakes, marshes, and drainage ditches, unless otherwise specified.

River aquifer (this report)—The aquifer that consists of permeable, partly saturated sediments and sedimentary rocks that are hydraulically connected to the Colorado River so that water can move between the river and the aquifer in response to withdrawal of water from the aquifer or differences in water-level elevations between the river and the aquifer.

Sea level—In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—A geodetic datum derived from a general adjustment of the first order level net of the United States and Canada, formerly called "Sea Level Datum of 1929."

Section, Township (T.), and Range (R.)—Locations used by the U.S. Geological Survey are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River (G&SR) meridian and base line, in California is based on the San Bernardino (SB) meridian and base line, in Nevada is based on the Mount Diablo (MD) meridian and base line, and in Utah is based on the Salt Lake (SL) meridian and base line.

Sediment—Solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice, or that accumulates by natural means such as chemical precipitation or secretion by organisms, and that forms in layers on the Earth's surface in unconsolidated form. Sediments generally consist of alluvium, mud, clay, silt, sand, gravel, boulders, carbonate muds, shell fragments, and organic material; in basins of interior drainage, sediments include salt (halite), gypsum, and other evaporite minerals.

Sedimentary rocks—Rocks resulting from consolidation of sediments. The rocks can be formed in marine, estuarine, and continental environments.

Static water level—The level of water in a well that is not being affected by ground-water withdrawal. The level to which water will rise in a tightly cased well under its full pressure head.

Water table—The surface in an unconfined aquifer at which pressure is atmospheric and below which the permeable material is saturated with water. The water table is the level at which water stands in wells that penetrate the uppermost part of an unconfined aquifer.

Method to Identify Wells That Yield Water That Will Be Replaced by Colorado River Water in Arizona, California, Nevada, and Utah

By Richard P. Wilson *and* Sandra J. Owen-Joyce

Abstract

Accounting for the use of Colorado River water is required by the U.S. Supreme Court decree, 1964, *Arizona v. California*. Water pumped from wells on the flood plain and from certain wells on alluvial slopes outside the flood plain is presumed to be river water and is accounted for as Colorado River water. A method was developed to identify wells outside the flood plain of the lower Colorado River that yield water that will be replaced by water from the river. The method provides a uniform criterion of identification for all users pumping water from wells by determining if the elevation of the static water table at a well is above or below the accounting surface. Wells that have a static water-level elevation equal to or below the accounting surface are presumed to yield water that will be replaced by water from the river. Wells that have a static water-level elevation above the accounting surface are presumed to yield water that will be replaced by water from precipitation and inflow from tributary valleys.

The method is based on the concept of a river aquifer and an accounting surface within the river aquifer. The river aquifer consists of permeable, partly saturated sediments and sedimentary rocks that are hydraulically connected to the Colorado River so that water can move between the river and the aquifer in response to withdrawal of water from the aquifer or differences in water-level elevations between the river and the aquifer. The subsurface limit of the river aquifer is the nearly impermeable bedrock of the bottom and sides of the basins that underlie the Colorado River valley and adjacent tributary valleys. The accounting surface represents the elevation and slope of the unconfined static water table in the river aquifer outside the flood plain and the reservoirs of the Colorado River that would exist if the river were the only source of water to the river aquifer. The accounting surface extends outward from the edges of the flood plain or a reservoir to the subsurface boundary of the river aquifer. Maps at a scale of 1:100,000 show the extent and elevation of the accounting surface from the area surrounding Lake Mead to Laguna Dam near Yuma, Arizona.

INTRODUCTION

Flow in the Colorado River is regulated by a series of dams, and releases of water through these regulatory structures are controlled by the United States. Water stored in reservoirs is released to meet downstream water requirements, to make storage available for flood control, and to generate power. Water from the Colorado River is diverted or pumped and used to irrigate croplands and to support wildlife habitat in the marshes along the river. Water also is pumped from wells in the Colorado River valley and adjacent tributary valleys for agricultural, municipal, industrial, and domestic uses. In the United States, accounting for the use of Colorado River water is required by a decree (U.S. Supreme Court, 1964); a report that contains records of diversions, returns, and consumptive use of water by individual water users is published annually (Bureau of Reclamation, 1965–92).

Water pumped from wells on the flood plain and from certain wells on alluvial slopes outside the flood plain is presumed to be river water and is accounted for as Colorado River water. Water pumped from some wells outside the flood plain has not been included in the accounting because the subsurface limits of the aquifer that is hydraulically connected to the river were not defined. No method was available for identifying wells that yield water that will be replaced by water from the river and wells that yield water that will be replaced by water from precipitation or inflow from adjacent tributary valleys. To aid in implementing the Supreme Court decree, a method was developed by the U.S. Geological Survey, in cooperation with the Bureau of Reclamation, to identify wells outside the flood plain of the lower Colorado River that yield water that will be replaced by water from the river. The method provides a uniform criterion of identification that is based on hydrologic principles for all users pumping water from wells.

Legal Framework

The Colorado River Compact of 1922 apportions the waters of the Colorado River between the upper basin States and the lower basin States (U.S. Congress, 1948, p. A17-A22). The requirement for participation of the U.S. Geological Survey and the Bureau of Reclamation is stated in Article V:

> The chief official of each signatory State charged with the administration of water rights, together with the Director of the United States Reclamation Service and the Director of the United States Geological Survey shall cooperate, ex-officio:
>
> (a) To promote the systematic determination and coordination of the facts as to flow, appropriation, consumption, and use of water in the Colorado River Basin, and the interchange of available information in such matters.

Water in the lower Colorado River is apportioned among the States of California, Arizona, and Nevada by the Boulder Canyon Project Act of December 21, 1928 (U.S. Congress, 1948, p. A213-A225) and confirmed by the U.S. Supreme Court decree, 1964, *Arizona v. California*, in terms of consumptive use. The decree is specific about the responsibility of the Secretary of the Interior to account for consumptive use of water from the mainstream; consumptive use is defined to include "water drawn from the mainstream by underground pumping." Article V of the decree (U.S. Supreme Court, 1964) states in part:

> The United States shall prepare and maintain, or provide for the preparation and maintenance of, and shall make available, annually and at such shorter intervals as the Secretary of the Interior shall deem necessary or advisable, for inspection by interested persons at all reasonable times and at a reasonable place or places, complete, detailed and accurate records of: * * *
>
> * * * (B) Diversions of water from the mainstream, return flow of such water to the stream as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation, and consumptive use of such water. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California, and Nevada; * * *

Article I of the decree defines terminology and states in part:

> (A) "Consumptive use" means diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation;
>
> (B) "Mainstream" means the mainstream of the Colorado River downstream from Lee Ferry within the United States, including the reservoirs thereon;
>
> (C) Consumptive use from the mainstream within a state shall include all consumptive uses of water of the mainstream, including water drawn from the mainstream by underground pumping, and including but not limited to, consumptive uses made by persons, by agencies of that state, and by the United States for the benefit of Indian reservations and other federal establishments within the state; * * *

Purpose and Scope

This report documents the method to identify wells outside the flood plain of the lower Colorado River that yield water that will be replaced by water from the river. The report defines and delineates the river aquifer in the lower Colorado River valley in Arizona, California, Nevada, and Utah (fig. 1); describes the source of water in the river aquifer; and describes the sediments and sedimentary rocks

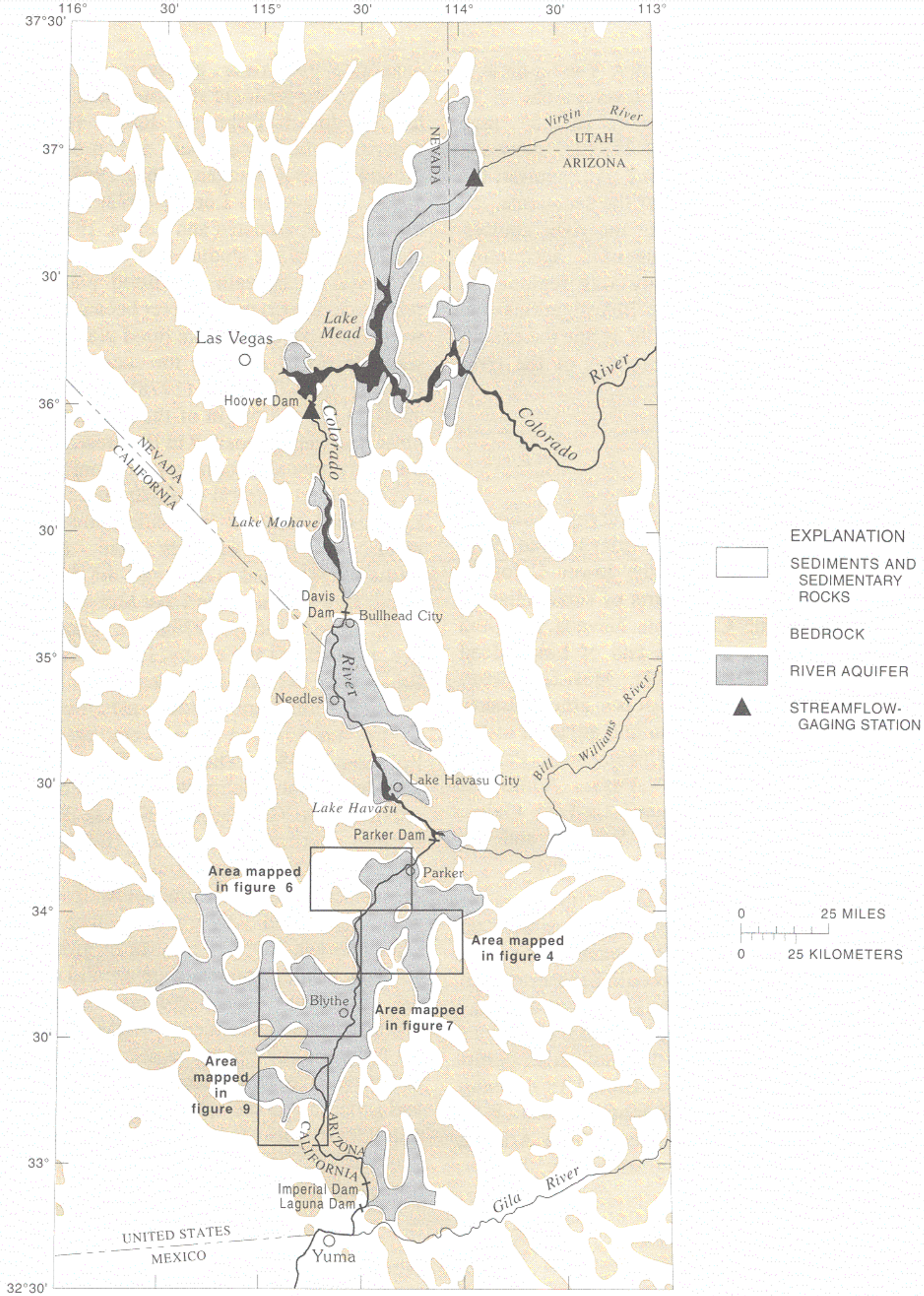

Figure 1. The lower Colorado River and areal extent of the river aquifer.

that transmit and store the water. The report also describes the concept and development of an accounting surface and contains an index map (fig. 2) and 19 maps (pls. 1-19) that show the approximate boundaries of the river aquifer, the generalized surface extent of the sediments and sedimentary rocks that form the river aquifer, and the elevation and contours of the accounting surface. Because the study was regional in scope, detailed site-specific investigations that would be required to precisely define the extent, thickness, or hydraulic properties of the river aquifer were not included.

Data Collection

The U.S. Geological Survey collected hydrologic data for the study from 1990 to 1993. The study area includes the lower Colorado River drainage area and parts of some adjacent valleys in Arizona, California, Nevada, and Utah and extends from the east end of Lake Mead south to Laguna Dam (fig. 1). Most field work was done on the alluvial slopes around Lakes Mead, Mohave, and Havasu and adjacent to the flood plain in Mohave, Chemehuevi, Parker, Palo Verde, and Cibola Valleys. Additional work was done in Cactus and La Posa Plains, Chuckwalla and Smoketree Valleys, and the Yuma Proving Ground. (See pls. 1-19.)

Wells outside the flood plain were inventoried and water-level measurements were made where owners permitted access to the wells and measuring instruments could be inserted into the well. Water-surface elevations in drainage ditches and marshes and land-surface elevations at many wells and gravity data-collection points were determined by use of Global Positioning System satellite surveys (Remondi, 1985). Well data are stored in a data base of the Arizona District of the U.S. Geological Survey, Tucson, Arizona.

Previous Investigations

Previous geohydrologic studies of the lower Colorado River valley from Davis Dam to Yuma defined and described the formations that constitute the river aquifer of this report, discussed the geologic structures and framework of the lower Colorado River valley, and described the occurrence and movement of ground water (Metzger, 1965, 1968; Olmsted, 1972; Metzger and Loeltz, 1973; Metzger and others, 1973; Olmsted and others, 1973). Major emphasis of these studies was the ground-water flow system beneath the flood plain and its relation to the Colorado River because few wells were available outside the flood plain to provide water levels or samples for chemical analysis. Eberly and Stanley (1978) described the stratigraphy and origin of the late Tertiary rock units that were deposited in the present basins of the study area and form an important part of the river aquifer. Several geohydrologic studies of Lake Mead National Recreation Area provided much of the geologic and hydrologic information needed to delineate the river aquifer above Davis Dam in the Lake Mohave and Lake Mead areas (Bentley, 1979a, b, c; Laney, 1979a, b, c, 1981; Bales and Laney, 1992; J.T. Bales and R.L. Laney, written commun., 1993). Regional geologic setting and Tertiary tectonic evolution of the Lake Mead area were described by Bohannon (1984). The Virgin River depression was defined and delineated from geologic and gravity data (Blank and Kucks, 1989) and seismic and gravity studies (Bohannon and others, 1993). Estimates of surface and subsurface tributary inflow below Hoover Dam were compiled by Owen-Joyce (1987). Chemical and isotope analyses of ground water and geochemical models were used to determine the processes that control ground-water chemistry and determine the origin and chemical evolution of the ground water along the lower Colorado River (Robertson, 1991). In compiling and generalizing the extent of the sediments and sedimentary rocks that form the river aquifer, 70 geologic studies and maps were used in addition to those cited above.

Acknowledgments

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